EPICYCLIC GEAR TRAIN FOR TURBO FAN ENGINE

BACKGROUND

The present invention is generally directed to gas turbine engines and, more particularly, to gear systems for use in variable cycle gas turbine engines. Typical turbofan gas turbine engines utilize a fan to generate two streams of air for producing thrust. The fan pushes a first stream of inlet air into a core turbine engine where the inlet air is used to sustain a combustion process. The first stream of inlet air is passed through a series of compressors, a combustor and turbines, which are disposed in an axially serial relationship. The compressors increase the density and temperature of the air for carrying out the combustion process in the combustor. High-energy gases resulting from the combustion process are then used to produce thrust and rotate the turbines. Typically, a first turbine is used to drive the compressors for the combustion process, and a second turbine is used to rotate the fan. The fan also pushes a second stream of inlet air around the core engine to directly produce thrust. Typically, each engine is configured with a fixed bypass duct that dictates the engine bypass ratio: the distribution of the inlet air routed to the core engine (primary air) and the inlet air routed around the core engine (bypass air).

Typically, turbofan engines are configured to operate optimally at one set of operating conditions, the design point of the engine. For example, many small military aircraft are configured with low bypass ratio engines, where rapid engine response time and high thrust are desirable. Conversely, high bypass ratio engines achieve lower noise emissions and better fuel efficiency and are therefore well suited for large transportation aircraft. Thus, the design point of a high bypass ratio turbofan is typically configured to operate at cruising conditions such that low thrust specific fuel consumption is achieved. At operating conditions above this design point, such as high-thrust takeoff conditions, specific fuel consumption increases as the engine requires more fuel for marginal thrust increases. Below this design point, specific fuel consumption also decreases as a disproportionate amount of thrust is lost as fuel usage is scaled back. These types of turbofans are sometimes referred to as single cycle engines, as the operating performance of the engine is tied to one specific thermodynamic cycle relating the air flow to the combustion process. Specifically, a single cycle engine is limited by the mass flow rate of the inlet air produced by the fan at any given rotational speed. Thus, an engine designer must choose between efficiency and performance in selecting the design point for a single cycle engine.

The operating range of a turbofan engine, and hence flexibility in the performance of the aircraft in which it is used, can be increased by varying the bypass ratio. Variable cycle engines operate in multiple modes, each with a different thermodynamic cycle in which the mass flow rates of each mode are selected to meet different performance needs. For example, two-cycle engines operate in either a high bypass configuration or a low bypass configuration, in which a variable bypass duct is typically used to divert inlet air from the bypass duct to the core engine. With the added flexibility, however, comes added complexity in matching air flow speeds, pressure ratios, mass flow rates, blade speeds and the like. For example, in order to accommodate the variable bypass duct, two-cycle engines frequently utilize two-stage fans having a large diameter forward section and a small diameter aft section. The forward section is thus able to push inlet air into both the bypass duct and the core engine. In one

configuration, however, these fan sections are connected to the same input turbine shaft. Thus, the speeds of each fan section cannot be individually controlled and blade tip speed control difficulties arise. In another configuration, the forward fan is connected to the low pressure turbine shaft and the rear fan is connected to the high pressure turbine shaft. Thus, the speed of each fan is governed by overall engine performance concerns rather than bypass ratio and mass flow rate concerns. There is, therefore, a need for a variable cycle fan section that permits individualized control over the rotational speeds of different fan sections.

SUMMARY

The present invention is directed to a two-stage turbofan system for use in a gas turbine engine. The two-stage turbofan system comprises a first-stage fan shaft, a second-stage fan shaft, a stationary torque tube and a gear system. The second-stage fan shaft connects with a drive shaft in the gas turbine engine such that the second-stage fan shaft is driven at the speed of the drive shaft. The stationary torque tube is connected with a fan case in the gas turbine engine. The gear system is connected to the second-stage fan shaft and the torque tube. The first-stage fan shaft extends from the gear system such that the first-stage fan shaft is driven at a speed reduced from that of the drive shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a schematic cross section of a two-stage turbo fan including an epicyclic gear system of the present invention.

FIG. **2** shows a schematic cross section of the epicyclic gear system of FIG. **1**.

FIG. **3** shows a front diagrammatic view of the epicyclic gear system of FIG. **2**.

FIG. **4** shows an exploded view of the epicyclic gear system of FIG. **2**.

DETAILED DESCRIPTION

FIG. **1** shows a cross sectional view of the propulsive section of variable cycle turbofan engine **10**, which includes two-stage fan section **12** configured for delivering multiple streams of inlet air I to turbofan engine **10** in order to vary the bypass ratio of engine **10**. Fan section **12** is configured to generate bypass air for producing thrust, and to generate core air for compressing in compressor **13**. The core air is used to sustain a combustion process within a core portion (not shown) of engine **10** positioned axially downstream of compressor **13**. Two-stage fan section **12** includes first-stage blade **14**A and second-stage blade **14**B that are inter-disposed between inlet guide vane (IGV) **16**, intermediate guide vane **18** and exit guide vane **20**. First-stage blade **14**A and second-stage blade **14**B are joined at their inner diameter ends to fan shaft system **22**, and vanes **16**, **18** and **20** are joined at their outer diameter ends to engine housing **24**. Fan shaft system **22** comprises fan shaft **26**, first-stage fan shaft **28**, second-stage fan shaft **30** and epicyclic gear system **32**. Engine housing **24** comprises inlet case **34**, gate **36**, fan case **38** and intermediate duct **40**. Fan section **12** and fan shaft system **22** comprise radially symmetric systems that are configured for rotating about axis A in FIG. **1**. Thus, fan section **12** includes circular arrays of first-stage blades **14**A, second-stage blades **14**B and vanes **16**, **18** and **20**, which are mounted to annular shafting members **26**, **28** and **30**.